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An analysis of the climate change architecture

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ABSTRACT

This paper examines the complexity of the current negotiations to avert climate change under the United Nations Framework Convention on Climate Change. Drawing on economic game theory modelling, it interprets the latest developments within the international negotiations and provides a political economy analysis of the climate change architecture. It places the pursuit of international co-operation, via the Kyoto Protocol's second commitment period, in the context of a country's maintenance of national interest and a flexible emissions abatement strategy.

Accepting that countries will reject an international agreement or obligation that is seen as inimical to their economic competitiveness, it incorporates a new game theory model, considers how learning from such models can influence agreement design and proposes a new approach from a non-monotonic polluting payoff function. Attention is placed on enabling conditions that entice countries to ratify a climate agreement, thereby encouraging participation and accelerating a near term deployment of low carbon technologies.

Contents

1. Introduction

Climate change is an important foreign policy for global leaders, where the power to make agreements often includes concerns that derive from individual nations. It is a collective action problem [1] that represents a significant market failure [2]. Achieving an international agreement can only happen if the various interests of

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Table 1
The Game Matrix (after Ciscar's multi-region exercise, 2000).

	c	*bau*	*si*
Comply with climate agreement (*c*)	*c*, *c*	*c*, *bau*	*c*, *si*
Business as usual (*bau*) [i.e. continue to pollute and apply no new policies/measures so maximises utility function without emissions reductions]	*bau*, *c*	*bau*, *bau*	*bau*, *c*
Self-interest (*si*) [i.e. consideration of climate change in context of the impact on own economy so maximises own utility function]	*si*, *c*	*si*, *bau*	*si*, *si*

Table 2
Abate/Pollute Game (after DeCanio et al. [9]).

U.S. strategy		Chinese strategy	
		Abate	Pollute
	Abate	a, w	b, x
	Pollute	c, y	d, z

Abate refers to early mitigation in current or near term, and Pollute refers to no mitigation.

In this game, *a* in the upper left hand segment is the payoff for the U.S., if the U.S. chooses the strategy *Abate*, and China chooses the strategy *Abate*. China's payoff is *w* from this pair of strategy choice. The payoffs to each of the players in the game are measured by order, so (a, b, c, d) and (*w*, *x*, *y*, *z*) can take on numeric values of (4, 3, 2, 1), with 4 as the most favourable outcome reducing to 1 as the least favourable outcome. Let us first assume, that the *Abate*: *Abate* outcome is preferred outcome for both parties, so no economic benefit arises if both *Pollute* instead of choosing *Abate*. Say, if the decision of neither party's pollution benefits the other party, then it is difficult to see if any benefit could be derived from emissions reductions resulting in either China or the United States [9]. As a result of the economic restrictions the decision *a* would also be greater than *d* ($a>d$, and $w>z$), while the no pollution restriction means $a>b$, $c>d$, and $w>y$, $x>z$.

individual nation states are met, while cost-effectiveness and overall national competitiveness is protected and maintained. Such economic considerations are very relevant as the only chance we have to curb climate change is to accelerate the growth of clean energy economies [3]. Progress and agreement depend on our understanding of how policy at a national level, and collective action at an international level, support and encourage each other [4]. This paper considers how to best achieve an agreement by reviewing existing game theory models, in light of the climate negotiations and by proposing a new approach with non-monotonic payoff function.

While climate change is an interconnected global problem where 'conflicts of interest are international and intergenerational' [5], it remains a geopolitical issue. The International Energy Agency (IEA) estimate that CO_2 emissions will double over the next four decades, a rise in average global temperatures of between three and six degrees [6]. Governments and policymakers are being urgently asked to act to reverse these trends and let scientific evidence inform their pathway. There is international acceptance that a global response to tackling climate change requires international collaboration that reflects the idea of a balanced and fair agreement. Achieving consensus surrounding climate is a significant collective action problem, where benefits are internalised within a country and the costs are evenly spread out globally. This raises issues concerning how best to reframe such an agreement, and what considerations to make in shaping its architecture.

2. Learning from game theory concepts

Throughout the past 50 years, game theoretical models have been applied to interconnected global problems, including financial markets, trade, biodiversity, international relations and, more recently, climate change negotiations. The business community relies heavily on game theoretical models (for example in market entry/exit, mergers and acquisitions and pricing) in terms of making decisions and or choosing a strategy they consider the potential choices of others. As an enterprise presents a willingness to co-operate, they heighten the chances of future co-operation and so reinforce a positive reputation that may influence future actions of other enterprises. Therefore, the dependency of future actions based on past outcomes informs the current choice of players[1] [7]. These theoretical models are useful in that they acknowledge that individual decisions depend on the expected reactions of others, allowing policy makers to form more effective and efficient policy mechanisms that focus on incentives. This had led Forgo, Fulop and Prill, [8 p. 252], to comment:

> 'It is hard to find a better testing ground for various game theoretic models than climate change negotiations where the conflict character of the situation is apparent not only for the specialists but also for concerned citizens.'

A player's (or a country's) decision is automatically informed by the decisions of another player, as a player aims to maximise their utility function, seek self-interest, and engage in 'free-riding'.

2.1. Applying game theory to the climate negotiations

Game-theoretical models provide an elegant formalisation of strategic interactions across the climate negotiations [9] whose application can inform parties' decisions given certain circumstances. A number of key assumptions surround the application of game theory to the climate negotiations, namely that countries will act rationally and will all share the objective of climate protection. Table 1 outlines the various combinations of strategies that parties can pursue, structured around three cases: compliance with agreement, continuing business as usual and applying self-interest strategies. Ciscar [10] found that the emissions levels of parties were similar in cases in which a strategy of self-interest (*si*) and compliance (*c*) with a climate agreement were pursued. Furthermore, in scenarios where one party followed a business as usual (*bau*), the other party followed a *si* strategy. From a game theory 'realism' perspective and using 2×2 order games, each

[1] 'For example, a manufacturer and a supplier will continue to do business as long as the supplier meets certain quality standards and the manufacturer pays a good price and provides sufficient volume' [7 p. 24].

Table 3
Nash's equilibrium within the game.

U.S. strategy	Chinese strategy: Abate	Chinese strategy: Pollute
Abate	3, 3	1, 4
Pollute	4, 1	2, 2

Deviation from business as usual strategy (a Pollute to Abate Strategy) may have a more negative payoff

The pollute/ pollute strategy where the payoff is equal (2, 2) and a pareto superiority (3, 3) arises from an *Abate*: *Abate* strategy. However, if one of the parties deviates from the *Pollute* Strategy, thereby moving to an *Abate* strategy, then the payoff (1) would be less than that of its original strategy of business as usual (*Pollute*: *Pollute*).

nation state ranks each of the expected outcomes and the resulting associated payoff(s).

From a climate perspective, we apply the *Abate/Pollute* strategy (Table 2) where two parties exist in the game: in this example the U.S. and China. There is considerable payoff for both parties as the costs of climate change exceed the costs of mitigation [11]. Both countries have openly expressed a fear of jeopardising economic growth and competitiveness that may be directly attributed to their abatement actions. So, we stimulate the consequences of current and near-future actions based on projections of future costs and benefits as players undertake, or choose not to undertake, mitigation measures to reduce greenhouse gas (GHG) emissions. In this game, *a* in the upper left hand segment is the payoff for the U.S., if the U.S. chooses the strategy *Abate*, and China chooses the strategy *Abate*. China's payoff is *w* from this pair of strategy choice. The payoffs to each of the players in the game are measured by order, so (*a*, *b*, *c*, *d*) and (*w*, *x*, *y*, *z*) can take on numeric values of (4, 3, 2, 1), with 4 as the most favourable outcome reducing to 1 as the least favourable outcome. Let us first assume, that the *Abate*: *Abate* outcome is the preferred outcome for both parties, so no economic benefit arises if both *Pollute* instead of choosing *Abate*. Say, if the decision of neither party's pollution benefits the other party, then it is difficult to see if any benefit could be derived from emissions reductions resulting in either China or the United States [9].

We then relax the assumption and we see how preferences change. The U.S. and China agreed on an *Abate*: *Abate* as the dominant Nash equilibrium strategy leading to the rational pursuit of self-interest that encourages co-operative behaviour [1]. In effect, neither party can improve their payoff by deviating away from their outcome if the second party also acts the same way and maintains the equilibrium (the maxi-min strategy). The payoff to the U.S. and China for choosing *Abate* is greater than their payoff for choosing *Pollute*.

2.2. Considering time and payoffs

Countries, such as U.S. and China, do not just make a decision about whether to pollute or not, they make a decision about when and by what level they wish to reduce their emissions so as to maximise their expected payoff. If we apply a (near and long-term) time horizon to our game early abatement actions may affect later abatement costs. Late mitigation costs are assumed to be the lowest when both countries undertake early abatement, higher when only one country undertakes early abatement, and highest when neither country undertakes early abatement. Less abatement in the near term will have significant impact, in cost terms, assuming that economies moves towards a low carbon trajectory in the longer term. This asymmetric dilemma implies the less action that occurs in the near term to reduce CO_2 emissions, the more expensive in nominal terms it will be to implement similar actions in the longer term. This often results in countries observing and not acting while others bear the abatement cost: if it is unclear who is going to pay the cost and who and what will be gained from acting, one has an energised set of opponents and a weak group of allies [12].

The *Prisoner's Dilemma* (PD) can be applied to study the complexity that arises when time horizons and costs are applied to the *Abate/Pollute* Game. As the financial costs associated with the time of abatement become significant and so the opportunity cost of action is considered. All gains are forfeited if the co-operative arrangement benefits another party [13] and complexity is added with a 'wait and see' abatement strategy [14]. The early adoption of technologies may be significantly more expensive than delaying to a time when costs have reduced and technologies have become more mature.[2] The counterfactual is early abatement providing 'first to market' advantages. Table 3 presents a scenario where Nash's equilibrium arises from both the U.S. and China maintaining a *Pollute* strategy. The real question is whether the payoff for exploiting one country's *Abate* co-operative strategy is better than their payoff for engaging in mutual co-operation (*Abate: Abate*) with another country.

In international relations, the strategic interaction between a pro-nuclear country and a country with an anti-nuclear stance is often cited. Each country's decision is a function of the actions of their counterpart and depends on their forecast of future behaviour. Both countries will strive towards conditions for equilibrium existence. Indeed, like Table 3, each country has two strategies, simultaneously interacting at once, with ordered preferences accorded to primary and secondary objectives and a matrix where each country strives to obtain the highest possible outcome given their counterpart's choice [15].

In terms of the Abate/Pollute Game, the *Pollute/Pollute* strategy where the payoff is equal (2, 2) and a pareto superiority (3, 3) arises from an *Abate*: *Abate* strategy. However, if one of the parties deviates from the *Pollute* strategy, thereby moving to an *Abate* strategy, then the payoff (1) would be less than that of its original strategy of business as usual (*Pollute*: *Pollute*).

Countries must also consider a preference for delay in their *Abate* strategy, especially considering the possibility that future technological learning may indeed reduce the costs associated with abatement in the longer term. This increases the attractiveness of delayed abatement strategies. The negotiations do not

[2] There is little acknowledgement inherent in the PD that a co-operative outcome could be reached if parties are permitted to signal to each other intent to co-operate [14].

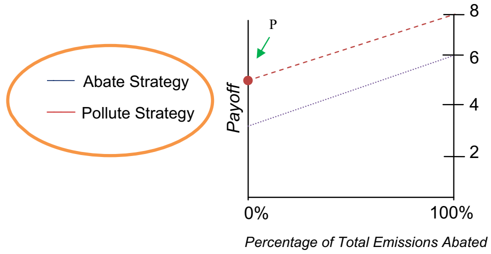


Fig. 1. The classical game theory approach (adapted from [9]: the prisoner's dilemma and coordination in N-player games). (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

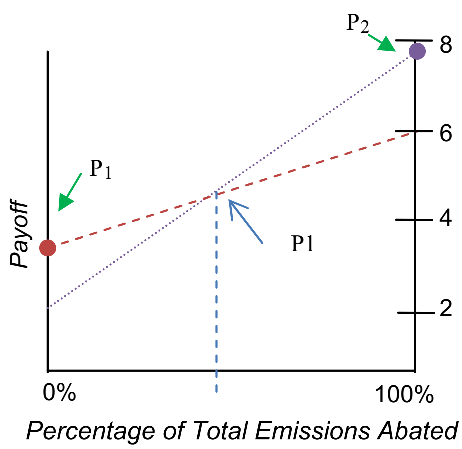


Fig. 2. The coordination game (adapted from [9]: the prisoner's dilemma and coordination in N-player games). (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

reflect this two party power struggle as depicted in Table 2, as attention focuses on how the one party's ‘payoff’ compares to what the second party has received, and vice versa.

In Fig. 1 the percentage of emissions abated by one negotiation strategy is considered in terms of potential strategy payoff. The PD logic applies as long as the *Pollute* strategy line is above the *Abate* line and one Nash equilibrium exists (represented by the dot in Fig. 1). The payoff to the polluting party increases as total emissions are abated, while the benefits from abating may also increase. However, the decision to *Pollute* has a negative externality as it results in pollution. This is the classical game theory approach incorporating the *Prisoner's Dilemma*. The horizontal axis measures the percentage of emissions abated and the vertical axis measures the payoff per country following their decision. In Fig. 1 the PD logic applies as long as the Pollute strategy line is above the Abate strategy line, therefore it does not matter if the *Abate* line slopes upward or not. The one Nash equilibrium is represented by the heavy red dot.

When considering a single UNFCCC binding agreement, coordination games become more complex when more than two countries exist in the negotiation. Once the two lines cross with the abate line upward sloping (Fig. 2), a coordination game commences as two Nash equilibria exist (as represented by two dots). In this two player dilemma, all countries can *Pollute* and all can *Abate*. If fewer than the payoff point (P_1) of the pollution is abated, then the payoff to *Pollute* is greater than the payoff to *Abate*. Fig. 2 presents the coordination game, where the optimum strategy depends upon the actions of others within the game. It is reflected at the point of intersection between the two lines cross and the *Abate* line is upward sloping. It exhibits two Nash equilibria, one in which all countries pollute (red dot) and the other in which all abate (blue dot).

In Fig. 2, if fewer than P_1 (payoff) percentage of total emissions is abated, then the payoff to abate is less than it is to pollute, and all countries will settle toward the equilibrium in which all *Pollute*. Yet, if more than P_1 of the pollution is abated, then the payoff to *Abate* is greater than the payoff to *Pollute*, and the countries will settle toward the equilibrium in which all abate. In a multi-country negotiation setting, as a number of countries shift to an abatement strategy (from *Pollute*), it entices other countries to also change their strategy in order to achieve payoff. Circumstances, such as an international climate treaty could transform a Figs. 1 into 2, where a shift upward would increase the slope or change the shape of the *Abate* payoff function so that the strategy lines cross. Rationally acting countries will settle toward the equilibrium in which all countries abate [8]. Payoffs to abate could include avoidance of climate change effects, while payoff to *Pollute* could include avoidance of investment costs required for emissions reduction. If the *Abate* strategy line were moved up, the P_1, pollution abated to induce co-operative equilibrium would shift to the left.

3. A critique of a centralised single agreement approach

This section identifies two main challenges with countries pursuing a top–down climate change approach. It analyses the appropriateness of such architecture with respect to the ‘global commons problem’ and in terms of the emerging ‘differentiation’ among developing countries.

3.1. The ‘global commons’ challenge

Politically, applying a single agreement to curb climate change is an exceptional challenging dilemma due to the ‘global commons problem’. For the majority of countries, the direct costs of action to curb climate change will inevitably be less than the direct benefits that result, despite the fact that global benefits may be greater than global costs [14]. Yet, the ‘early adaptor’ country bears the full costs of its emissions reduction while only receiving a small fraction of the resulting benefits. While agreement may be easier across countries that are artificially symmetric, principles such as fairness and equity play a role. This reflects public choice theory where engagement by a country within the climate negotiations only occurs when the co-operation is associated with a net gain for that country [15]. Considering the majority of national action requires constituent support, a main challenge is that ‘climate change is essentially unobservable to the general population’ [16].

The IEA's reference scenario [17] indicates that, by 2030, developing countries will experience an 85% increase in global energy demand and 97% increase in energy related CO_2 emissions. Such change and accompanying GHG emissions are projected to occur mostly in the developing world, particularly China, India and the Middle-East, with estimates indicating that India's emissions could increase by three to four fold by 2030, ranging from 4 to 7 billion tonnes [18]. Given their need for continued economic growth, it is unlikely that developing countries will agree to constrain emissions without compensation from developed countries [19]. The transfer of these technologies, typically from industrialised nations to developing countries, provides an avenue for ‘spillover’ effects, where compensation stimulates changes in flows of capital, production and trade between countries and regions.

Seeking national self-interest could have positive ‘free rider’ effects as it is economically rational for a country to let another country lead and be first to abate CO_2 emissions. The continual struggle of nations to assert such national interest ends up hurting the common interest [20]. This analysis led the OECD to call for Governments to ‘break out of their national mindsets and look at

Table 4
Comparison of CO_2 emissions of major economies (UNEP Gap Report and PBL Netherlands Assessment Agency [2012]).

	Emissions (including land use)/capita, tonnes CO_2/capita			
	1990	2010	2020 BAU	2020 Pledges
EU-27	11.9	9.2	10	8.8 (20% reduction) 7.7 (30% reduction)
China	3.5	7.4–8.3	9.9	9.7
United States	24.3	21.5	21	17.7

the global picture' as it calls for more 'policies to build a low carbon, climate resilient economy' [21].

3.2. Differentiation among developing countries

As long as CO_2 emissions accumulate within the atmosphere and their sources are greater than sinks, the historical responsibility of countries will have a scientific basis in the climate change research. As developing countries currently account for nearly 55% of GHG emissions, a differentiation among developing countries becomes a realistic proposition. This differentiation should be considered along a spectrum that emphasises the current capabilities of an individual developing country. Any new agreement architecture should consider the current circumstances of developing countries and economies in transition, rather than views and categories held when the Convention was signed in 1992. The commitments to address climate change and the rules for counting and tracking emissions can no longer be handled on a bifurcated basis (based on 1992 categories). 'We should not have the same expectations for emerging powers like China, Brazil, Mexico or Korea as we have for countries of modest capacity just because all of them are developing' [3]. The significant economic interests between different countries, that are partly diametrically opposed, has made the mission to negotiate such a single binding agreement 'near impossible' [22].

It could be argued that a number of these economies should no longer be the beneficiaries from climate financing as, from 2009 to 2011, their GDP was higher than the average EU 27 states.[3] Attention could focus on the circumstances of poorer countries that have made a minimal contribution to climate change, thereby maintaining principles of equity across the agreement architecture. When analysing incomes and emissions per capita of the U.S., EU and China (until 2020), it becomes clear that, based on current business as usual scenarios, carbon emissions, in the form of CO_2 tonnes per capita, are practically the same for both the EU and China, but half those of the U.S. [see Table 4].

Reverting back to game theory, accepting the costs of abatement outweigh the benefits, international co-operation is essential for achieving agreement. Negotiation positions return to the economic benefit (or differential cost) of abating early or abating late. The perceived ratio of benefit-to-cost is often dependent on the action of others: a country's failure to act can result in another country reconsidering its abatement strategy. Stern and Rydge [4] describe how international action depends strongly on the national decisions of countries where commitment to agree can result in an enhanced national willingness and determination to meet obligations. However, achieving consensus around structure is more challenging than ever, especially considering issues of equity ('common but differentiated responsibilities') and emerging vibrant emerging economies (such as Singapore and United Arab Emirates) that are classed as developing nations. These nations need to increase their level of ambition within a future agreement.

Vogler [1] describes how, once the U.S. failed to ratify Kyoto, the main strategy from Russia, Japan and Australia was to maximise potential emissions while minimising all penalties resulting from non-compliance. This issue of growth and competitiveness is again central where the linking of growth to emissions productions may indeed be viewed by emerging economies as a form of punishment that would prevent certain countries from emerging to challenge the US and European economies. Strives toward co-operation and gaining trust bring a potential risk of exploitation [24] as one country may feel vulnerable if a second country fails to reciprocate.

One of the key issues surrounds the failure to apply adequate enforcement mechanisms. Saul and Seidel [25] outline the enforcement weaknesses of the climate regime and the subsequent impact on meeting responsibilities under the Convention. Breaking the agreement has little or no negative consequences making the lack of a binding agreement an impediment to international climate co-operation. With trust must come enforcement responsibilities: the requirement for having clear binding commitments should be linked with the achievement of economic interests [26].

4. Designing a flexible architecture while maintaining ambition

Under the UNFCCC, individual countries bargain within a group of nearly 200 nations based upon a generally shared appreciation of the scale of the climate challenge. In reality, this reflects a multistage game: a simultaneous negotiation at a national and international level where interactions occur across interest groups at a national level, while coalitions are built at an international level. The classic two stage game, outlined by Putnam [27], Berk and del Elzen [28] and Rong [29], describes how central government tries to alleviate domestic concerns without committing to any action that will have deleterious effects at home. Implications for competitiveness, development and growth are high on national agendas.

Climate authors and policy makers have publicly debated the arrangements required to solve the climate change dilemma. Achieving an all-inclusive top–down agreement that includes all country compliance with strict timetables and targets is perhaps overly ambitious. One single set of targets, applicable to all, may not be appropriate to the multiple interests of nation states. While such ambition may work on paper, demanding the achievement of, and policing compliance with, strict commitments through tough penalties may be viewed as undermining national competitiveness. A spectrum or range of targets or negotiation points, possibly in the form of pledges or a hybrid portfolio approach, may be a more flexible and acceptable strategy.

Establishing a flexible framework for policy implementation, at a nation state level, is perhaps more relevant and achievable than a harmonised climate change target. This needs to be conducive to broad country participation and should encourage emerging

[3] These countries include Qatar, Singapore, Kuwait, Brunei Darussalam, United Arab Emirates, Equatorial Guinea, and the Bahamas [23].

economies to be ambitious and act, while achieving a level of differentiation among developing countries [3]. Mitigation commitments that focus on national planning provide flexibility. For example, EU countries had the opportunity, through national planning, to determine their levels of renewable heat and electricity ambition within their National Renewable Energy Action Plans. Reframing the climate architecture can take this one step further by formally acknowledging key national action such as a country's investment in clean technology, recognising energy efficiency gains or decreases in energy intensity across the economy.

The next section explores a number of dimensions when reframing the climate architecture and includes:

4.1 Embracing national, bilateral and multilateral action
4.2 Adopting a Pledge approach that reflects National differences
4.3 Considering national competitiveness
4.4 Utilising 'spillovers' as incentives
4.5 Game theory and domestic action

4.1. *Embracing national, bilateral and multilateral action*

National action ultimately becomes the necessary instrument to fulfil an international agreement. There is general consensus [1,13,30] that the inclusion of the large emitting countries in any agreement architectural design and ratification is essential to curbing future GHG emissions. Today, just 20 countries and regions account for nearly 90% of global emissions and so national, bilateral and multilateral action is essential. Undoubtedly, the extension of the Kyoto Protocol commitment period was a critical bridge towards reaching a binding deal in 2015 (through the 'Doha Gateway') and in maintaining a rules-based and common accounting system. While it is extremely unlikely that a favourable outcome, in an emissions reduction sense, will arise from countries acting individually [2], this second commitment period achieved minimal signatories[4] (representing 10–12% global emissions) and reflects the design inadequacies of the original Kyoto Protocol from a major emitter perspective. China, Indonesia, India and Brazil were not constrained due to a lack of commitments, while the U.S. passed legislation to promote clean technology, improve efficiency and reduce GHG through regulation but failed to ratify.

Country-to-country arrangements have the potential to undermine future Kyoto model agreements, often in the pursuit of national economic interest. For example, Bang et al. [31,2] described how the U.S. engaged in a *Partnership on Clean Development and Climate* with global coal producers, including India and China, to exchange knowledge on cleaner coal technology and has also established bilateral science agreements to facilitate technology transfer. The EU has signed science and technology cooperation agreements with developed countries and has engaged in joint research (*FP*7 and *Horizon* 2020) calls with Brazil, Russia and India, while also signing an agreement with China on strengthened environmental technological cooperation. The UK established *Climate Innovation Centres* in India and Kenya aimed at strengthening economic ties with its priority development countries.

4.2. *Adopting a 'pledge and review' approach that reflects national differences*

The merits of a 'pledge and review' approach to emissions reduction, utilising bilateral and multilateral finance, have long

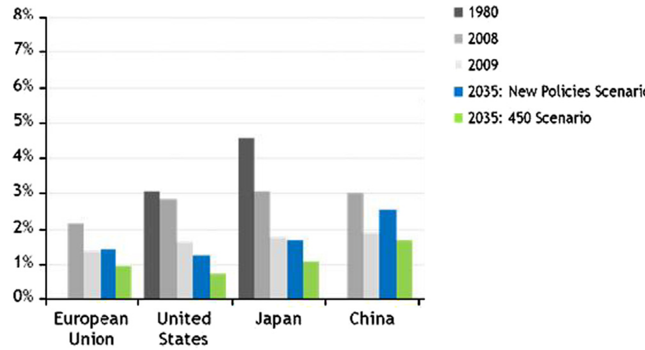


Fig. 3. Oil-import bills as share of GDP in selected countries [17].

been debated [26,32,33]. This bottom–up perspective, ignoring the 'free-rider' problem, espouses the belief that climate change can be stabilised when effective change is driven by local action and driven by the attainment of domestic goals [34]. Maintaining cost-effectiveness in attaining climate goals through a least-cost means is critical. The 'Kyoto model' does not provide strong enough incentives for parties to participate or comply. The most prudent and cost effective path may require a slow ramp up of target severity for participating parties, and a phased approach that avoids unnecessary capital stock obsolescence [35]. The 'Cancun Agreement', building upon the 'Copenhagen Accord', failed to deliver a global binding agreement. It enabled government pledges that included monitoring, reporting and verification of emissions reductions across all countries. At a general level, an agreement on commitments of the 'Cancun Agreement' involved an acceptance of the principle of GHG limits, voluntary pledges from parties to reduce emissions in the near term, and sectoral deliverables. While geopolitical uncertainty surrounded the ratification of the 'Durban Declaration' by key emitters, future arrangements may hinge on the national policies to curb emissions and the integration and alignment of such plans and co-operation into the international architecture. Nation interests and emerging political change may significantly impact the ratification of the 'Durban Declaration' post 2015. Indeed, as we get closer to ratification, the interests of individual nations may overpower the collective interest.

4.3. *Considering national competitiveness*

National interest is linked to economic wealth. Countries are subsumed by budgetary crises and political opposition has undermined strives towards achieving consensus and has discouraged more ambitious commitments to emissions reduction. Government leaders have to respond to policy demands to secure indigenous sources of energy supply, constituent demands for more aggressive environmental policies, and the recognition that neither demand can be met without continued competitiveness and economic growth.

Grasso [34], Brennan [36] and Grundig [37] argue that national market failure can be remedied by collective action. No single country, or group of countries can solve the climate change problem and coordinated action is absolutely necessary [11]. While the UNFCCC focuses on achieving climate effectiveness through reductions in net GHG emissions, little consideration is placed on factors, such as economic cost. The economic benefit that arises from curbing emissions should be made more explicit. The IEA's 450 ppm *Scenario* to 2035 [6] estimates that annual spending on oil imports by the five largest importers is around $560 billion, or one-third, lower than in the *New Policies Scenario* (see Fig. 3). This analysis highlights the economic savings (from

[4] This commitment period to 2020 will only include EU, Australia, Norway, Switzerland and a few smaller countries such as Lichtenstein and failed to include Canada, Russia, Japan and New Zealand.

reduced oil-import dependency) that can be achieved from pursuing a low carbon technology strategy.

The 2 °C/450 ppm stabilisation target has 'a primarily environmental rather than an economic rationale' and if the cost of achieving the target exceeds the benefit, then the goals of benefit-cost optimisation and climate effectiveness would diverge [38]. The impact on a countries' national autonomy versus the benefits of achieving a global agreement is a growing consideration for major economics. Larger parties, such as China and the U.S., do bear a small but non-negligible fraction of the costs of global CO_2 emissions and are eager to placate public opinion at home and avoid international pressure [39].

Prior to UNFCCC Conference of the Parties in Durban, the expectation was that emerging economies, such as Brazil and China, in their pursuit of national interest, would be less likely to apply a voluntary commitment to place emissions caps on their respective economies. Any reframing of climate architecture should consider the inequalities of participating countries and recognise that countries are driven by domestic issues of competitiveness and political self-interest above agreement acceptability and GHG abatement. Indeed, Bang et al. [31] observed that participating countries will consider the distribution of power, preferences and possible coalitions in their strategy to accept or reject an agreement. Rong [29] illustrates such factors that influence policy response, including a country's ecological vulnerability, mitigation capability, international financial and technological transfer and country pressure arising from growing GHG emission levels.

4.4. Utilising 'spillovers' as incentives

Authors, including Bazilian et al. [39] and DeCanio [9], have argued that the transfer of low-carbon technologies is essential to achieving participation from any developing countries in a future agreement. These concessional mechanisms can bring beneficial effects in the form of technological knowledge on the productivity and innovative ability of countries. Beccherle and Tirole [40] outlines how a country's strategic positioning increases the cost of delay in choosing to abate emissions as future technological or societal choices will be linked to concession extraction arising from the negotiations. While it is challenging to reliably quantify the impact of such 'spillovers'[5], they remain a significant negotiation incentive to attract parties toward a climate change agreement and are valuable preconditions for long-term technical innovation [2].

'Spillovers' are 'elaborate concessions' for participation in the climate architecture. They arise from economic and geopolitical relations and could provide a stimulus to national growth, resulting in increased emissions [41]. International commitments are obtained when countries perceive advantages from participation in terms of innovation and low carbon growth [4]. Beccherle and Tirole [40] and Harstad [42] have argued how countries will bias their moves so as to extract concessions in future climate negotiations. For example, under the *Poznan Strategic Programme*, a $50 million fund was established to scale up investment in technology transfer. Beneficiaries included Brazil, Cambodia (technology transfer using agricultural residue biomass for sustainable energy solutions), Chile (promotion of local solar technologies), China (green truck demonstrations), Kenya, Jamaica (introduction of renewable wave energy technologies for the generation of electric power) Thailand (overcoming barriers to support technological innovation and south-south technology transfer, ethanol production from Cassava), and Sri Lanka (Bamboo processing).

4.5. Game theory and domestic action

The climate change negotiations are a collective action problem where, similar to any game, focus is placed on cooperation and on the strategic interactions of individual countries. The welfare of an individual country depends on its own GHG emissions and on the emission levels of all other countries. Game theory focuses on the mathematics behind the strategic behaviour of countries, or put another way, the tools to help them to determine what they perceive to be in their best interest. Game theoreticians model the climate negotiations as extensive games of perfect information, applying and analysing solution concepts such as Nash equilibrium and bargaining solutions.

A number of game theoreticians, from the classical co-operative to the non-cooperative authors [41–44], have applied game theory to the problem of international climate change negotiations given the strategic interdependencies among countries. Such models involved the creation of network incentives for adoption [44], simulated country pathways for GHG abatement [43], and explored coalition formation and its impact on outcomes as assumptions change. Such individual game models are based on decisions around different levels of mitigation efforts and are useful for showing what happens to the probability of co-operative outcomes once assumptions are relaxed. While the UNFCCC negotiations themselves are not a *PD*, addressing GHG in the absence of international coordination is very similar to a *PD* and will possibly lead to a sub-optimal outcome. A valid *Prisoner's Dilemma* matrix can be transformed into an alternative game as a result of players having different motives and perceptions and in how players in the game can interpret various scenarios.

Free-rider effects emerge through voluntary cooperation and influence the negotiations. These effects have a negative impact if one country emits more CO_2 than agreed, and another country then deviates from their agreed targets in the following commitment period. Attention is placed on incorporating the appropriate incentives that will get nations to cooperate. This links cooperation on climate change with cooperation on other issues, such as trade ('border tax adjustment') and adaptation finance.

Even with the concentrated effort of country negotiations throughout the past two decades, some game theoreticians argue that governments will most likely fail to conclude a major international treaty to reduce atmospheric concentrations of GHG and, even in the unlikely event of achieving such an agreement, believe it most likely will not work. Universal treaties will either (a) not demand countries to change what they are doing or (b) demand fundamental changes in behaviour without applying credible monitoring and sanctioning provision [45].

The climate negotiations pose challenges for game theoreticians as no single model can be readily applied that captures all players' strategic behaviours at play. Game theoreticians find it easier to reach an agreement through modelling artificially symmetric countries rather than modelling agreement as a dynamic process. Achieving agreement assumes countries are symmetric so the effect of climate change unequally impacts upon countries. As Eyckmans [46] puts it, more research is needed to understanding the heterogeneous players rather than the symmetric players. This will require other methods beyond the analytical tools that are being applied by game theoreticians.

Global problems do not always require global solutions. As key countries are deemed unwilling to take on burden-sharing the validity of such an international approach to agreement is being questioned. National policy makers have argued that legal activism

[5] Examples of 'spillover' incentives include the instigation of fast-track financing, low-carbon technology transfers, reduction of intellectual property barriers or restrictions, enhanced trade agreements, technology innovation development and demonstration (RD&D), regulations, standards or suitable instruments to induce the necessary required investment in technology transfer.

through domestic laws, rather than a global agreement, is the approach to curb the negative effects of climate change. In a *Globe* study of 33 countries, the number of new domestic environmental laws has risen from 10 a year in the early 2000 to 20 in 2012. While countries such as Mexico, South Korea and Japan introduced environmental legislation in 2012, developing countries passed twice as many environmental laws as developed countries did [47]. While such legislation may not be a suitable measure, the public seems more willing to accept domestic environmental laws rather than international ones.

5. Proposing a new flexible approach

This section of the paper reframes the climate architecture by proposing a portfolio approach. This represents a hybrid [48] between a 'pledge and review' bottom–up approach to emissions reduction and top–down targets and timetables (as seen in a second commitment period Kyoto model). It tailors targets to the needs of countries and so reflects the complexity and uncertainty of projecting emissions for developing countries [44]. It reflects differentiation across developing countries and applies a new spectrum of emissions whereby national competitiveness can be maintained.

The proposed method, utilising a non-monotonic payoff function, has been applied in previous research. Chowdhury [49] and Arora et al. [50] have adopted this approach when discussing patent valuations in terms of 'all-pay auctions' where bidders simultaneously bid for prizes, whose valuation is affected by the bid. This analysis cites the dependence of a patent's value on corresponding R&D expenditure. An enterprise may earn a patent on a particular product if it can innovate the product before its rivals; and at the same time, the enterprise's payoff is bigger if the product is of higher quality due to a higher volume of R&D expenditure [50]. Further payoff examples include the level of influence over government decision making gained through lobbying expenditure and the 'all-pay contests' where a bid will monotonically affect prize value.

Game theory shows us that there are differences in decision making between governments or parties that are caused by differences in their perception of the payoff during certain interactions. Fig. 4 presents the implications of a non-monotonic function, and illustrates the payoffs for a single country. The optimal portfolio may depend on the risk in climate damages, and this does not change monotonically in risk. Considering the international climate negotiations at a global level, the incentive for parties to abate increases, their negotiation strategy is pushed to the right (to P_2) and their percentage of emissions abated increases.

Investigation of game theory and coalition formation often assumes that countries are symmetric: a country's payoff function that is monotonically increasing with coalition size. Carraro [51,52] in describing complex coalition structures and agreements around international R&D co-operation, describes the intent of such R&D co-operation is about increasing the efficiency of technology, while lowering its production cost. However, as the coalition of numbers of agreement signatories increases, competitive advantage shrinks, due to enhanced technology sharing, making it in some cases more optimal to exclude some countries from joint R&D co-operation. This case provides some insight into the specific characteristics of countries as refers to cases that are asymmetrical in nature. If this R&D co-operation model is applied to the climate agreement process, it reinforces countries as non-myopic where coalitions are formed endogenously.

The structure of a climate agreement is a crucial ingredient in the negotiation process and may impact upon the probability of

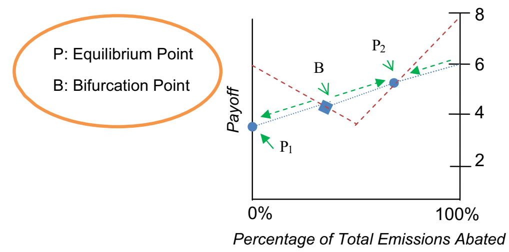


Fig. 4. A non-monotonic payoff function. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

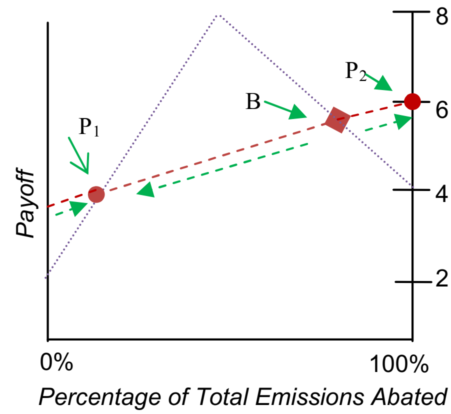


Fig. 5. Model with a bilinear polluting function. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

stabilising climate change. Countries have different resource availabilities, different natural resource endowments, are different sizes and are often at different stages of development. As Carraro [51] states 'if all countries negotiate on a single agreement, the incentives to sign are lower than those which characterise a multiple agreement negotiating process'.

Figs. 4 and 5 present two negotiation points or mitigation policy options with non-monotonic payoff function. The figures have a dashed red line to represent the payoff under a 'pollute' strategy and a blue line to represent the payoff ('*y*-axis') under an 'abate' strategy. These lines are functions of the percentage of total emissions abated, the '*x*-axis'. P_1 and P_2 reflect the two equilibrium points. Conversely, as the pollute payoff increases (or abate payoff decreases) the strategy is pushed to the left (to P_1) and the country's percentage of emissions abated decreases. Considering the negotiations from a nation state perspective, countries will act differently depending on the payoff that they perceive from their chosen strategy. For example, a country would move from bifurcation point (B) to either P_1 or P_2 depending on what positive or negative payoff or 'spillover' they can gain. This is often based on socio-economic perceptions and perspectives of entry, such as positive gains in terms of jobs, carbon credits, tax incentives or negative gains in terms of increased climate financing. This relates to behavioural game theory approaches that assume bounded rationality as countries learn and adapt during their climate negotiation interactions and attempt to predict likely human behaviour as a way of improving performance against adversaries [53].

It may cost more for a major economy to continue to pursue an emissions abatement strategy, given the competitiveness focus being driven by industry. For example, Germany, as a large producer of photovoltaics, biomass and wind energy, could exceed its emissions target of say 40% by say 2016, and could then choose, for competitiveness reasons, that it is no longer feasible (from a payoff perspective) to follow its existing strategy and so moves to

a pollutant strategy. This decision would require consideration of the political implications [1] of clean energy growth on its economy in the context of the cost of potentially continuing to abate for little reward or payoff. The domestic landscape is important as countries assess what can be agreed in the context of what can be ratified by their government at home [27].

Fig. 5 presents a new approach with a bilinear polluting function and a new game in the context of non-monotonic payoff function is incorporated. It highlights when a bilinear polluting function: the bifurcation point (B) exists as countries can select their strategy based on perceived 'spillover' advantages. This is an incentive based model of motivation (derived from motivational psychology) and considers how countries have different intrinsic preferences for incentives. Countries often view incentives differently mainly due to the non-monotonic and non-concave nature of motivation functions. Such incentives take the form of 'spillovers' that enhance investment in new frontier technologies and their subsequent transfer. For example, a country may revert to a pollutant strategy if they deem it more economically advantageous than following a course of emissions abatement. A country would be pushed to the left (away from B) and towards P_1. In such a model, rather than having a harmonised global goal of emissions reduction, (say 20%), we can apply a country based pledge approach per country, say 15% and 20%.

6. Conclusion

This paper analysed the latest developments within the international negotiations. It acknowledged the challenge of defining the required architecture to curb the imminent impact of growing CO_2 emissions. It identified a number of challenges that could hinder the achievement of a strategy based on the objective of achieving a single harmonised top–down agreement, similar to the Kyoto Protocol type model. The paper suggests that a reframed architecture could consider the role of national, bilateral and multilateral action and the importance of incentives, such as spillovers, to entice the engagement of countries. It incorporated a new game theory model and presented a new scenario with a non-monotonic polluting function. It reframed the climate agreement architecture by proposing new dimensions that could add flexibility.

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